Pre-stressed Geodesic Gridshell

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Abstract
Timber gridshells can cover large spaces with minimum material. However, with long-term creep deformations, small cross sections and high elasticity, there are potential stability issues. Historically, pre-stressing systems have been shown to prevent instability modes in unstable structures. In this project we investigate the benefits of pre-stressing a geodesic elastic bending-active gridshells serving as a lecture pavilion. Digital analysis and physical tests are interactively combined to study and implement various modelling and analysis techniques, pre-stress configurations and connection details. It is found that an internal pre-stressing system can significantly increase the stability of in terms of eigenfrequencies.

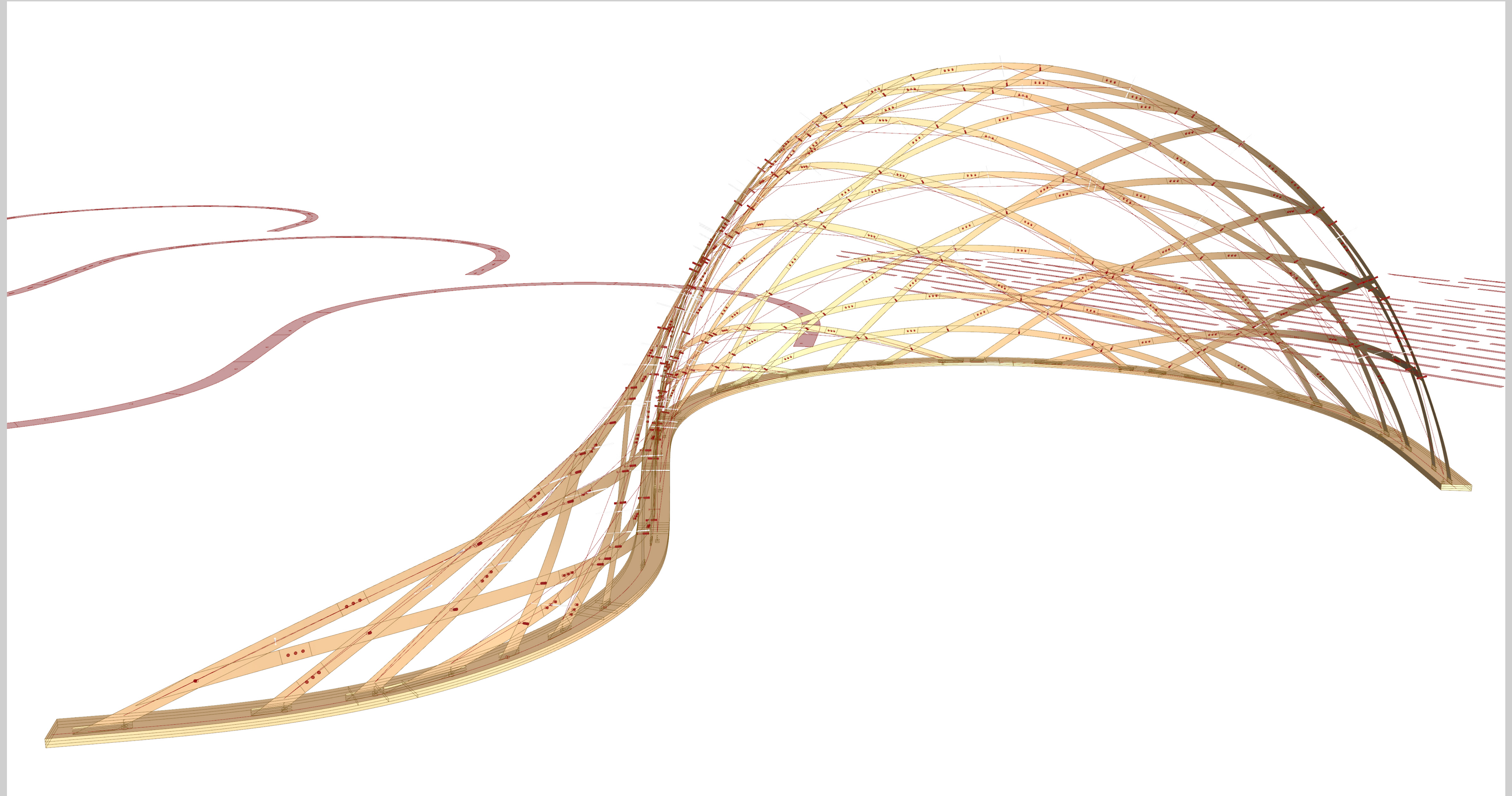

Figure 1: Final pavilion design in Rhino/Grasshopper with unrolled laths and base plate segments in the background.

Method
The design of the pavilion was developed as part of a master thesis project by Isaksson and Skeppstedt (2018). Using an iterative design process several possible concepts for space and structre were explored, evaluated and further developed in to possible concepts, and then later into one viable design proposal: an actively bent geodesic gridshell prestressed by means of a set of lightly pre-stressed cables (fig. 1). The hypothesis was that the cables would increase the overall stiffness of the pavilion, enabeling large the light-weight structure to span 8 meters across the stage. The pavillion was then designed according to the flowchart in Figure 2.

The pavilion was prefabricated, shipped and erected and then exhibited August 28-31 at the Wood Products & Technology 2018 fair in Gothenburg serving as a lecture pavilion (fig. 3). During the erection, load-deflection tests were conducted prior and after installing the cabels.

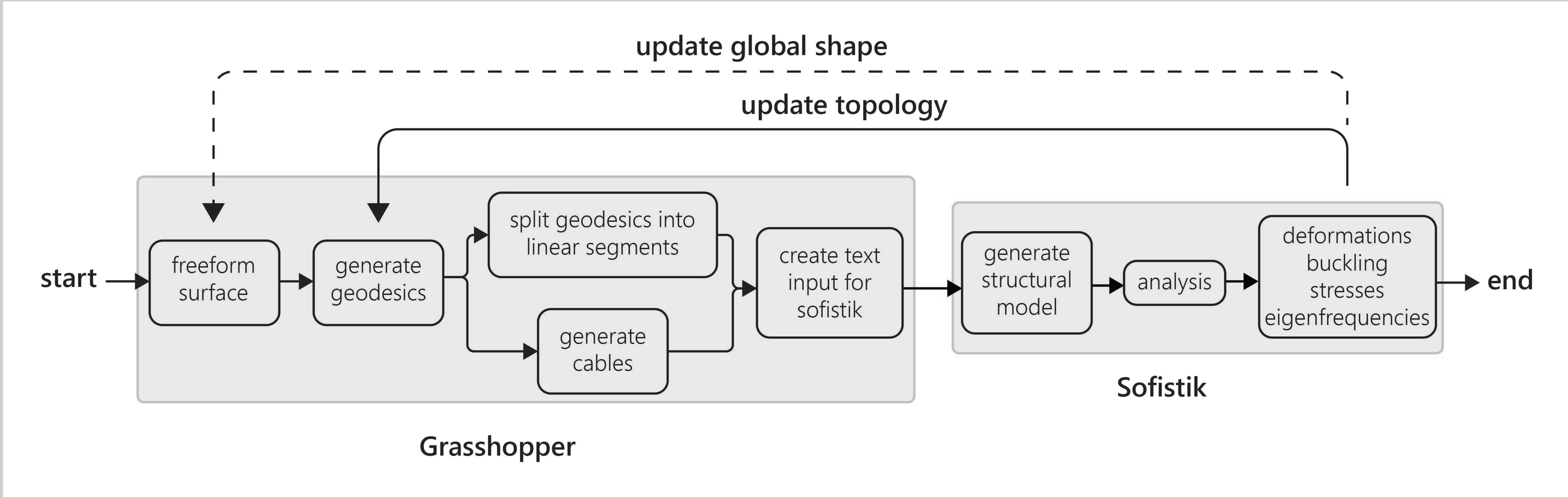

Figure 2: Flowchart of geometry definition and analysis process.

Figure 3: The "Wood Fusion Pavilon" at Wood Products & Technology 2018.

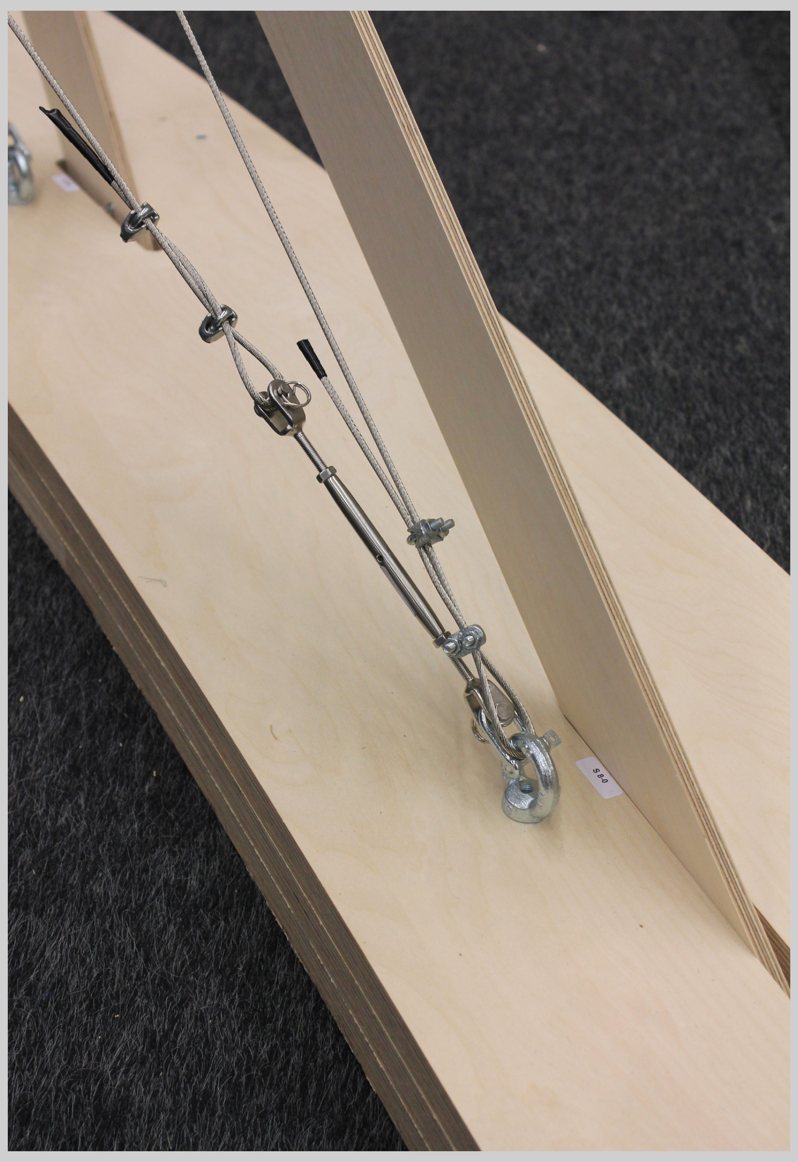

Figure 4: Cable connection.

Figure 5: Lath curvature effected by pre-stress.

Result
Following the eigenvalue method proposed by Lienhard (2014), the stiffness—and inevidently the stability—of the structure was investigated. The stresses arising when actively bending the laths were taken into acount in the analysis. The studies showed that the inclusion of the bending stresses had a slight increase in the eigenfrequency and thus a positive contribution to the stability.

Furthermore, a parameter study was carried out on the effect of the eigenfrequency and eigenmodes as a function of the number of equal length cable segments. It was found that an increase in the number of segments caused a rise in the eigenvalues.

Preliminary analysis from load-deflection tests performed on the built pavilion shows a significant stiffness increase when the cables were installed. Further analysis of the data and comparison with analysis results are needed for further conclusions.

However, there were imperfections in assembly causing deviations between the full scale geometry and the computer model and there was also flexibility of the cable end connection (fig. 4). This meant that it was not possible to pre-stress the structure to the level planned in the analysis. The curvature of some of the laths was affected too much and stress levels had to be reduced to ensure the global geometry without risking local buckling (fig. 5).

Future Work
Further analysis will be conducted on the results gained from building the full-scale pavilion.

References
Isaksson, J. and Skeppstedt, M. (2018). “Stressing timber”, Chalmers University of Technology.
Lienhard, J. (2014). “Bending-Active Structures”, University of Stuttgart.